The Effect of Night Temperature on Cotton Reproductive Development

Carolyn A. Zeiher, Paul W. Brown, Jeffrey C. Silvertooth
Nkonko Matumba, and Nancy Mitton

Abstract

A field study was initiated in the summer of 1993 to investigate the effect of increased night temperatures on cotton reproductive development. DPL 5415 was planted on May 10. Treatments consisted of two temperature regimes placed in a completely randomized design with four replications. The two temperature treatments were initiated at first bloom and treatments terminated after 6 weeks. Cotton grown under ambient night temperature served as the control treatments while plants where the infrared radiation balance was modified to increase the nighttime foliage temperature served as the high night temperature treatment. This study showed that increasing the nighttime foliage temperature of cotton reduced vegetative dry matter production, plant height, and fruit retention. The photosynthetic capacity of the two treatments was not significantly different, suggesting that increased respiration at these higher nighttime foliage temperatures may be responsible for the reduction in assimilated carbon which contributed to the poor fruit retention.

Introduction

Temperature is the primary environmental factor controlling the developmental rate of cotton. The rates of seed germination, vegetative and reproductive growth, and the timing of flowering and fruit maturation are all influenced by temperature. Previous studies suggest that cotton requires a low night temperature cycle during flowering for normal reproductive development. This observation may be particularly significant in the Desert Southwest during the monsoon when night temperatures can rise as much as 5^{O}C-10^{O}C relative to the night temperatures during the drier portions of the summer. It has been suggested that high night temperature contributes to the low boll retention observed during the primary fruiting cycle of cotton grown in this region.

Despite the possible effect night temperature has on cotton reproductive development, very few temperature studies conducted on cotton have separately evaluated day and night temperatures. There have been two independent studies which examined specifically the night temperature effect on boll retention. Both studies showed that cotton grown at elevated night temperatures retained fewer bolls (3,5). However, both of these studies were conducted on cotton plants grown under controlled environments which is not a realistic emulation of the arid environment typical to the Desert Southwest. The objective of the present study was to determine if increases in nighttime temperature affect the growth dynamics of field grown cotton.

Materials and Methods

Delta and Pine Land (DPL) 5415 (*Gossypium hirsutum* L.) was planted on May 10, 1993 at the University of Arizona Campus Agriculture Center. Treatments consisted of two temperature regimes placed in a completely randomized design with four replications. Each experimental plot was 6 m x 6 m with a 1 m row spacing. Two night temperature regimes were initiated at first bloom and were maintained throughout the primary fruiting cycle. Cotton grown under the ambient night temperature environment served as the control treatments (CTRL) while plants grown under a modified night temperature (MNT) environment served as the high night temperature treatment. To impose the MNT environment, large (6 m X 6 m) shelters were constructed and placed over the cotton canopy. These shelters consisted of a 6 m X 6 m frame composed of chain link fence which was suspended over the cotton canopy using 9 steel poles. At dusk, a nylon reinforced polyethylene tarpaulin covered with aluminum was unrolled over the shelter frame. This tarp was designed to modify the infrared radiation balance of the cotton canopy at night by significantly reducing the loss of long-wave terrestrial radiation. We theorized that if we could prevent the loss of infrared radiation, the foliage temperature would increase similar to what would occur during the monsoon season with increased humidity and cloud cover. The tarp was left on throughout the night and removed at sunrise the following morning. To add additional heat to the shelters, thermoresistive wires were attached to plastic gutters and gutters attached to the chain link fence at sunset. The gutters were lined with aluminum foil so that heat generated by the wires would be reflected back into the cotton canopy. The heaters were removed at sunrise when the tarps were rolled back up. Cotton foliage temperature was continuously monitored using infrared thermometry.

Dry matter accumulation was monitored in MNT and CTRL plots. Four plants were harvested from each experimental plot between 0800 and 0830 just prior to treatment initiation and then again at 10 day intervals for the duration of the treatments. The harvested plants were separated into leaves, stems (plus petioles), squares, and bolls, dried at 100°C for 1 h then for 3 days at 60°C. Non-destructive measurements were also taken when the night temperature treatments were imposed and at 7 day intervals for the duration of the treatments. These measurements included plant height, number of mainstem nodes, node position of the first fruiting branch, the number of mainstem nodes between the top white bloom and terminal (NAWB), fruit retention and canopy closure.

Yield determinations were made at crop maturity. Seed cotton was hand harvested from 1 m^2 areas of each experimental plot, ginned, and percentage of lint turnout determined.

Results and Discussion

Typical diurnal profiles of CTRL and MNT foliage temperatures are shown in figure 1. The foliage temperatures were similar during the day before the tarps of the MNT environment were unrolled at sunset. After the tarps were unrolled, the foliage temperature of the MNT environment was higher by 1°-6°C than the CTRL environment. The foliage temperature of the MNT environment returned to the CTRL foliage temperature when the tarps were rolled back up at sunrise. The temperature differential between the MNT and CTRL environment changed throughout the night period because of changes in cloud cover and wind speed. Increasing cloud cover reduces the loss of terrestrial long wave radiation in the CTRL plots. Higher wind speeds dissipated some of the heat generated by the MNT environment and accelerated sensible heat transfer to cooler CTRL foliage. The net result of the increased cloud cover and higher wind speeds was to bring the CTRL and MNT foliage temperature closer together.

The average nighttime temperature differential between the CTRL and the MNT environment for the 6-week treatment period ranged between 2°C-6°C (figure 2). The average temperature differential for the entire treatment period was 3.5°C. The higher temperature differentials occurred when the relative humidity was low and there was no cloud cover. The temperature differentials were reduced during monsoon season because the higher relative humidity and increased cloud cover lessened the net nocturnal loss of infrared radiation from the CTRL environment.

At treatment initiation, the cotton plants in the designated CTRL and MNT plots were similar in dry weight, plant height, the number of mainstem nodes per plant and the percentage of fruit retained (data not shown). After 6 weeks of the MNT environment, the MNT plots showed less dry matter accumulation in leaves, stem, squares, and bolls (Table 1). Although stems were the only organs that showed significant differences at the 0.05 probability level, the dry matter accumulation in the respective plant parts from the MNT plots showed increasing divergence with time after treatment initiation from the dry matter that accumulated in the corresponding plant parts of the CTRL plots. In addition, the cotton plants exposed to the MNT environment were shorter and retained less fruit (Table 2). By the last sampling date, these differences were significant at the 0.01 probability level. Exposure of plants to the MNT environment ($P \leq 0.01$) affected the number of mainstem nodes. Plants, after six weeks of MNT environment, had 21.75 nodes compared to 23.75 nodes for the CTRL environment.

Yield determinations were made at crop maturity. The plants exposed to the MNT environment showed a 43% and 42% reduction in lint and seed weight per unit area, respectively (table 3). The higher nighttime foliage temperature had no effect on the percentage of lint turnout.

The reduction in dry matter accumulation per plant, plant height, fruit retention per plant and yield per unit area observed for cotton plants grown in the MNT environment did not appear to be due to the shelter frame altering the photosynthetic capacity of these cotton plants. A comparison of the amount of photosynthetically active radiation (PAR) received by the cotton canopy over a 18 h photoperiod between the two treatments showed that the daily rates of photosynthetically photon flux density (PPFD) in the MNT plots averaged only 3.5% below those of the CTRL plots (figure 3). The PPFD received by the MNT plots was beyond the light saturation point for photosynthesis reported for cotton (4). In addition, leaf photosynthetic measurements taken from a fully expanded leaf at the top of the canopy from both CTRL and MNT plots showed no significant differences in leaf photosynthetic rates between these treatments.

In summary, these field studies showed that the MNT environment was effective in increasing the foliage temperature at night. The cotton plants experiencing this increase in nighttime foliage temperature showed a reduction in dry matter accumulation, height, and fruit retention which suggests that these plants had limited photosynthate available for growth and development. The similarity in PPFD received by the cotton canopy and the leaf photosynthetic rates between the two treatments suggest that this reduction in assimilate supply was not due to a reduction in the photosynthetic capacity of the plants exposed to the MNT environment. Since respiration is known to increase with temperature (1,2), increased respiration at these higher nighttime foliage may be responsible for the reduction in assimilated carbon which ultimately contributed to the poor fruit retention in the MNT environment.

Literature Cited

1. Baker, D. N., Hesketh, J. D. and Duncan, W. G. 1972. Simulation of growth and yield in cotton: I. Gross photosynthesis, respiration, and growth. *Crop Science* 12: 431- 435.

2. Brown, K. W. and Thomas, J. C. 1980. The influence of water stress preconditioning on dark respiration. *Physiol. Plant.* 49: 205-209.

3. Guinn, G. 1974. Abscission of cotton floral buds and bolls as influenced by factors affecting photosynthesis and respiration. *Crop Science* 14: 291-293.

4. Osmond, C. B., Winter, K., and Ziegler, H. 1979. Functional significance of different pathways of CO_2 Fixation in Photosynthesis. In *Encyclopedia of Plant Physiology* (eds. Gibbs, M., and Latzko, E.) vol. 6. pp. 479-547.

5. Powell, R. D. 1969. Effect of temperature on boll set and development of *Gossypium hirsutum*. *Cotton Gr. Rev.* 46: 29-36.

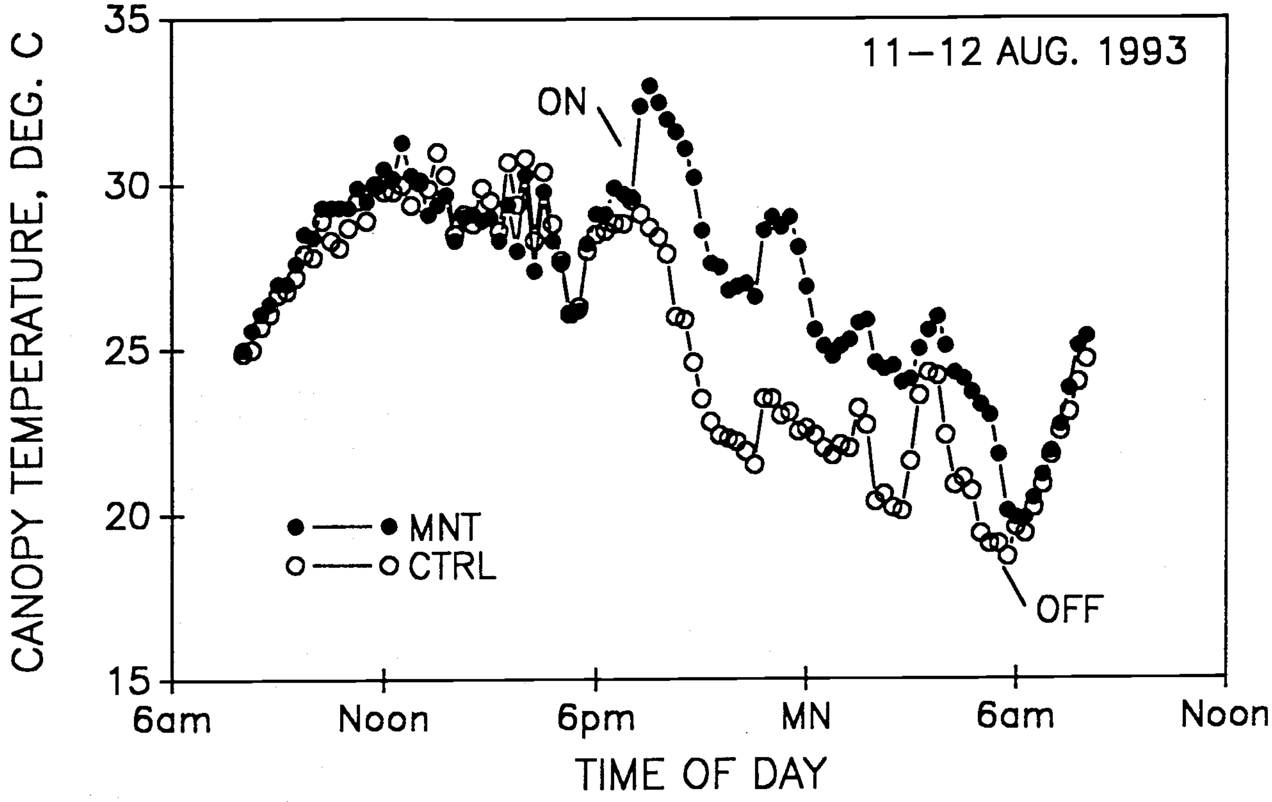

Figure 1: Diurnal profile of canopy foliage temperature in the CTRL and MNT plots. The tarpaulin cloth was pulled over the MNT plots at sunset (indicated by on) and removed at sunrise (indicated by off).

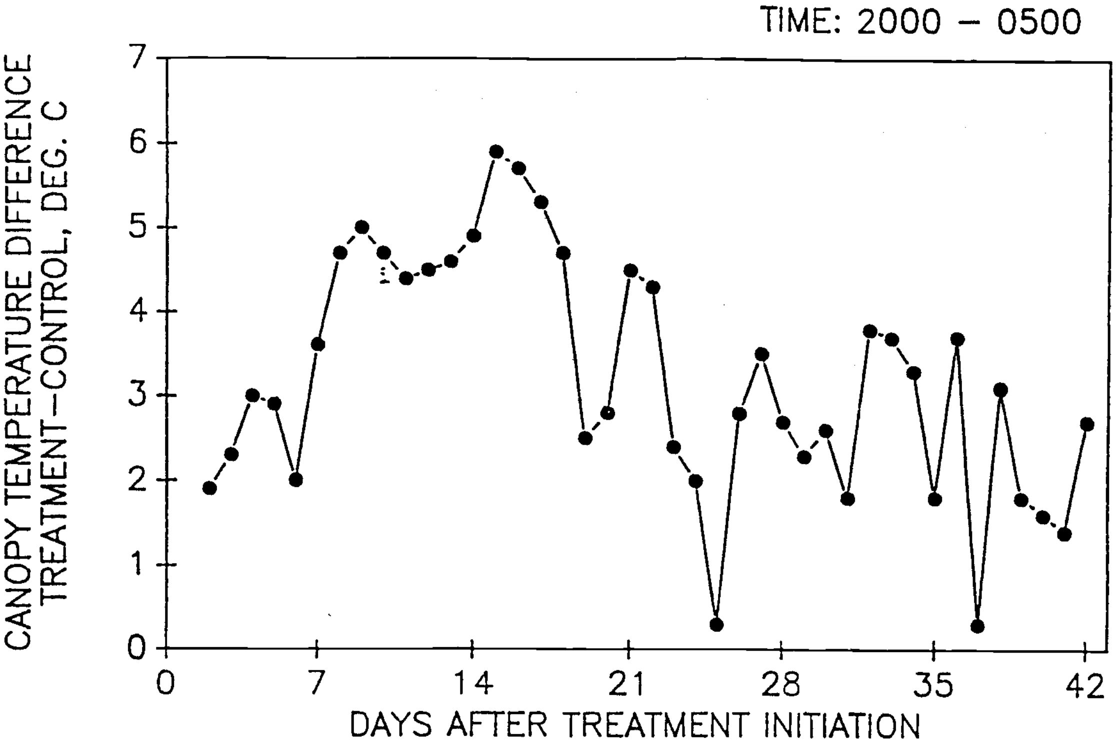

Figure 2: The average foliage temperature differences between CTRL and MNT plots observed at night for the duration of the treatments.

Table 1: Biomass accumulation in the different plant organs determined at the completion of MNT treatment

	----------g (plant)$^{-1}$----------			
	Leaves	Stems/Petioles	Squares	Bolls
CTRL	45.9 ± 3.2[τ]	56.1 ± 5.5[*]	1.1 ± 0.4	75.8 ± 6.5
MNT	36.2± 2.8	38.9 ± 2.4	0.2 ± 0.1	64.9 ± 7.1

[τ] mean ± standard error of mean

[*] significant at the 0.05 probability level

Table 2: Plant height, mainstem node number, and fruit retention measured at the end of the MNT treatment

	Plant Height (cm)	Mainstem node Number	Fruit Retention (%)
CTRL	100.3 ± 4.2[τ]	23.8 ± 0.4	66.9 ± 4.3
MNT	78.1 ± 3.3[**]	21.8 ± 0.2[**]	48.4 ± 1.8[**]

[τ] mean ± standard error of the mean

[**] significant at the 0.01 probability level

Table 3: Effect of MNT environment on lint and seed yield and lint turnout percentages

	----------kg / ha-----------		
Treatment	lint	seed	% lint
CTRL	2590 ± 261[τ]	3751 ± 383	40.4 ± 0.5
MNT	1467 ± 110**	2186 ± 187*	39.9 ± 0.3

[τ] mean ± standard error of mean

* and ** significant at a probability level of 0.05 and 0.01, respectively

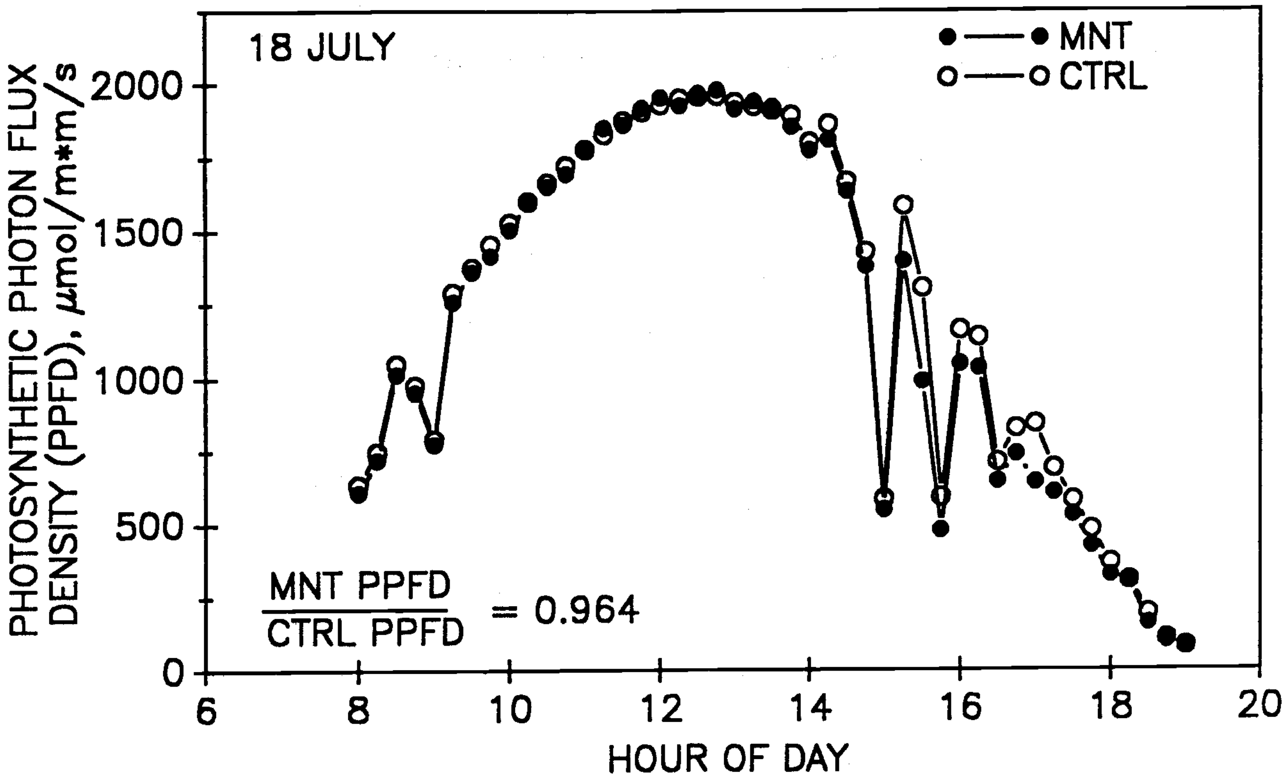

Figure 3: Comparison of the PPFD received by the cotton canopy in the CTRL versus MNT plots.